Project Category: Cross-Ecosystems

Project Title: The Washington Connected Landscapes Project: Providing Analysis Tools for Regional Connectivity and Climate Adaptation Planning

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Partners: The Washington Wildlife Habitat Connectivity Working Group (WHCWG) is a science-based collaboration of land management agencies, NGOs, universities, and Washington Treaty Tribes. The group is co-led by Washington State Departments of Fish and Wildlife (WDFW) and Transportation (WSDOT), with active participation from The Nature Conservancy (TNC), Conservation Northwest (CNW), Washington Department of Natural Resources (DNR), US Forest Service (USFS), US Fish and Wildlife Service (USFWS), Western Transportation Institute (WTI), and University of Washington (UW).

Cooperators: Joanne Schuett-Hames (WDFW, Joanne.Schuett-Hames@dfw.wa.gov, 360-902-2695) is co-leader of the WHCWG and will coordinate with ongoing WHCWG efforts, including GIS and communications. **Darren Kavanagh** (TNC, dkavanagh@tnc.org, 206-343-4345) will provide programming and software release support. **Brian Cosentino** (WDFW, Brian.Cosentino@dfw.wa.gov, 360-902-2376) is WHCWG GIS lead and will provide data for testing in the Columbia Plateau. **Sonia Hall** (TNC, shall@tnc.org, 509-665-6611) will coordinate with the Arid Lands Initiative to ensure our products meet land manager needs. **Joshua Lawler** (UW, jlawler@u.washington.edu, 206-685-4367) will provide input on connectivity mapping and climate corridor methods. *See Table 3 in Budget attachment for leveraged support.*

Project Summary: The Washington Connected Landscapes Project is a highly leveraged effort to provide scientific analyses and tools necessary to conserve wildlife habitat connectivity. Connectivity tool development is an integral element of the Project. We are requesting **$76,363** to: 1) develop tools necessary to reliably identify and prioritize areas important for wildlife movements under current conditions and for allowing species range shifts under climate change; 2) test and refine these tools by applying them in a Great Northern LCC (GNLCC)-funded effort to identify essential habitats and linkages for the Columbia Plateau Ecoregion where the WHCWG is currently engaged (connectivity tools) and across Washington State (climate tools); and 3) make these tools freely available and accessible as open-source GIS toolboxes. Together this work will provide valuable information and tools that will directly contribute to the NPLCC's efforts to strengthen regional capabilities for designing and implementing connectivity conservation strategies in the face of climate change.

Project Proposal

Need: Managing for well-connected landscapes is a key strategy to enhance resilience and ensure the long-term viability of plant and animal populations. Connectivity conservation is also the single most frequently cited climate adaptation strategy (Heller & Zavaleta 2009); many species will require highly permeable, well-connected landscapes both to maintain dispersal and gene flow as vegetation patterns and disturbance regimes change and to allow adaptive range shifts.

The need for connectivity conservation planning, including consideration of climate change, has been identified by several management and planning entities within the NPLCC. WDFW's Comprehensive Wildlife Conservation Strategy (2005) cited habitat conversion, fragmentation, and degradation as the most serious statewide threats to Washington's wildlife, and habitat connectivity and climate change have since been elevated to among the top planning priorities for WDFW. Washington State's Integrated Climate

Change Response Strategy cites conserving habitat connectivity across a range of environmental gradients as its first near-term goal to facilitate climate adaptation for species, habitats, and ecosystems (Washington Department of Ecology 2011). More broadly, governors of 19 western states have called for connectivity maps to help reduce the negative impact of energy development, urbanization, and highway projects (Western Governors' Association 2008).

Despite these needs, only a handful of regional conservation planning efforts have included connectivity. Moreover, despite numerous calls to increase connectivity across climatic gradients to accommodate climate-drive range shifts, there has been a lack of approaches proposed to rigorously map the areas needed to accomplish this (Beier et al. in press).

The WHCWG 2010 statewide connectivity analysis identified broad-scale priority areas for connectivity conservation (WHCWG 2010). More detailed, finer-scale ecoregional analyses will give land managers the information they need to begin prioritizing and implementing conservation actions. With GNLCC support, we are developing and testing our methods in the Columbia Plateau Ecoregion, which, along with the Puget Trough-Willamette Valley, was identified as being the most fragmented in our study area (WHCWG 2010). Additionally, as part of our statewide analysis, the WHCWG has developed and tested approaches to map important connectivity areas that span climatic gradients for climate change adaptation (Nuñez et al. in prep). We now have an opportunity to synthesize results from these analyses, which span large portions of the GNLCC and the NPLCC, with WHCWG statewide map layers to provide decision support regarding interpretation and implementation of these new climate products.

The spatial analysis tools we created for our statewide analysis provide ideal platforms for developing the tools needed for detailed ecoregional analyses and mapping corridors along climatic gradients. Our pilot analysis and tool testing in the highly fragmented Columbia Plateau (connectivity tools) and across Washington State (climate tools) will result in robust, transparent, and repeatable methods and tools that will increase the efficiency of subsequent ecoregional analyses, fine-scaled linkage designs, and climate gradient analyses in the NPLCC and elsewhere.

Objectives: The proposed work will provide decision support tools to assist with identification and prioritization of areas important for wildlife habitat connectivity under current conditions and for climate adaptation, thus advancing planning efforts across the NPLCC and the adjacent GNLCC.

Objective #1. Develop spatial analysis tools for ecoregional connectivity analyses and climate adaptation planning. We will enhance existing corridor mapping tools to identify choke points (areas where corridors narrow, creating bottlenecks where connectivity could be easily severed; Fig. 1), identify areas where restoration could most greatly enhance connectivity (Fig. 1), and prioritize linkages and core areas with high network centrality (those which are particularly important for connectivity across an overall network of core habitat areas; Fig. 2). We will also automate spatial analysis methods developed by the WHCWG to identify areas important for species range shifts along climatic gradients. These methods have been tested at the statewide scale (Fig. 3; Nuñez et al. in prep), and their automation will make them readily applicable to ecoregional-scale analyses and to analyses in new regions.

Objective #2. Test and refine analysis tools as part of GNLCC-funded Columbia Plateau connectivity analysis. Our spatial analysis tools will support ecoregional and statewide connectivity and climate analyses proposed in our March 2 GNLCC funding request (WHCWG 2011a). This work will build upon our broad-scale statewide products by 1) completing a more detailed connectivity analysis of the Columbia Plateau Ecoregion using the enhanced connectivity modeling methods described above, and 2) providing synthesis and decision support based on our statewide analyses of areas expected to be important for species range shifts under climate change. These analyses will allow us to test and refine our tools while directly informing conservation decisions, and will result in a template for connectivity and climate analyses in other regions.

Objective #3. Release above spatial analysis tools for public use. We will provide fully documented and open-source GIS tools for future use by the WHCWG and by conservation practitioners in the NPLCC, GNLCC, and in other regions.

Methods: Our methods and cooperator roles are described below; see Table 3 for leveraged support.

Objective #1. Develop spatial analysis tools. *Linkage Mapper*, an open-source ArcGIS toolbox we created for our statewide analysis (McRae and Kavanagh 2011; www.waconnected.org/habitat-connectivity-mapping-tools/) and *Circuitscape* (McRae and Shah 2009; www.circuitscape.org) provide ideal platforms for developing the tools needed for our ecoregional scale analyses. We will first integrate *Linkage Mapper* with *Circuitscape* to incorporate detection of choke points and restoration opportunities using circuit theory (McRae et al. 2008; Fig. 1). We will also develop a network version of *Circuitscape* to implement network centrality analyses needed to prioritize among linkages and core habitat areas (Fig. 2). Lastly, we will develop *Linkage Mapper Climate,* which will automate methods developed and tested by the WHCWG to map areas expected to be important for species range shifts (Fig. 3). These novel methods first identify natural areas that differ in temperature or moisture. They then use anisotropic cost-distance analyses to map corridors that avoid both areas with high human impact and areas with unsuitable climates by using layers of development and underlying climatic gradients as separate input layers (Fig 3; Nuñez et al. in prep). **Cooperators:** TNC, UW, WDFW.

Objective #2. Test and refine analysis tools. We will work closely with WHCWG members completing the Columbia Plateau Ecoregional connectivity analysis, supporting their efforts by providing and revising tools as connectivity analyses are completed. These activities directly support completion of several tasks described in our FY11 GNLCC request, including Task 1.1, *Complete wildlife habitat connectivity analysis across the Columbia Plateau*; Task 1.2, *Develop products and methods in ways that best inform conservation decisions;* and Task 2.2, *Identify connectivity areas most likely to facilitate species movements in response to climate change* (see WHCWG 2011a). We will refine our tools based on feedback from two workshops with the Arid Lands Initiative (ALI). We will also continue to work closely with the Western Governors' Association's pilot project in Washington, Idaho and Oregon to apply our tools to their connectivity and climate work. **Cooperators:** All WHCWG partners and the ALI.

Objective #3. Release tools for public use. We will release enhanced versions of *Linkage Mapper* and *Circuitscape* that add functionality described above. We will also release *Linkage Mapper Climate* as a new tool to automate climate corridor mapping. All will be provided as fully documented, open-source software with user guides to support their application to other landscapes in the NPLCC and beyond. Our *Linkage Mapper* code repository (http://code.google.com/p/linkage-mapper/), developed with GNLCC funds for our 2010 statewide analysis, provides a template for project hosting, version control, issue tracking, documentation, and user support. **Cooperators:** TNC, WDFW, and CNW.

Geographic Extent: Our tools will be developed for use in any regional or local-scale conservation planning context, and tested in the Columbia Plateau ecoregion of Washington, Oregon, and Idaho (enhanced linkage maping), and across all of Washington State and adjacent portions of Oregon, Idaho and British Columbia (climate gradient maps).

Timeline of Schedules, Products, and Outcomes: Starting AUG 2011, this project will build on model, data, and methods development funded through an FY10 GNLCC grant and a FY11 GNLCC request. We have already made considerable progress on overall objectives (see WHCWG 2011b).

Objective #1: Develop spatial analysis tools:
- Prototype integration of *Linkage Mapper* and *Circuitscape* for pinch-point detection: APR 2011
- Prototype tools to identify connectivity restoration opportunities: MAY 2011
- Prototype of *Circuitscape* with network analysis capability for centrality measures: JUL 2012

-Prototype of *Linkage Mapper Climate*: JUL 2012

Objective 2: Test and refine tools (Funds for this portion covered in FY11 GNLCC funding request):
-Two Arid Lands Initiative workshops to obtain enhanced linkage modeling feedback: SEP 2012
-Online report, maps, and decision support for statewide climate linkage analysis: DEC 2012
-Enhanced linkage products (choke points, restoration opportunities, centrality) online: FEB 2012

Objective 3: Public release of GIS tools with user guides and ongoing support:
-Release integrated tools to identify choke points and restoration opportunities: AUG 2012
-Release Network version of *Circuitscape* to prioritize linkages and core areas: NOV 2012
-Release *Linkage Mapper Climate*: FEB 2013

Product Dissemination: As with our statewide analysis, reports, maps, and tools will be available at www.waconnected.org. Interactive maps from GNLCC-funded portion of this work will be hosted on a databasin.org gallery devoted to the Washington Connected Landscapes Project. Tools and source code will be hosted at code.google.com/p/linkage-mapper/. We will submit manuscripts on climate adaptation corridors and choke point/restoration analyses to international journals beginning APR 2012, and present to a minimum of 4 diverse stakeholder groups by APR 2013. A final report will be submitted by JUN 2013.

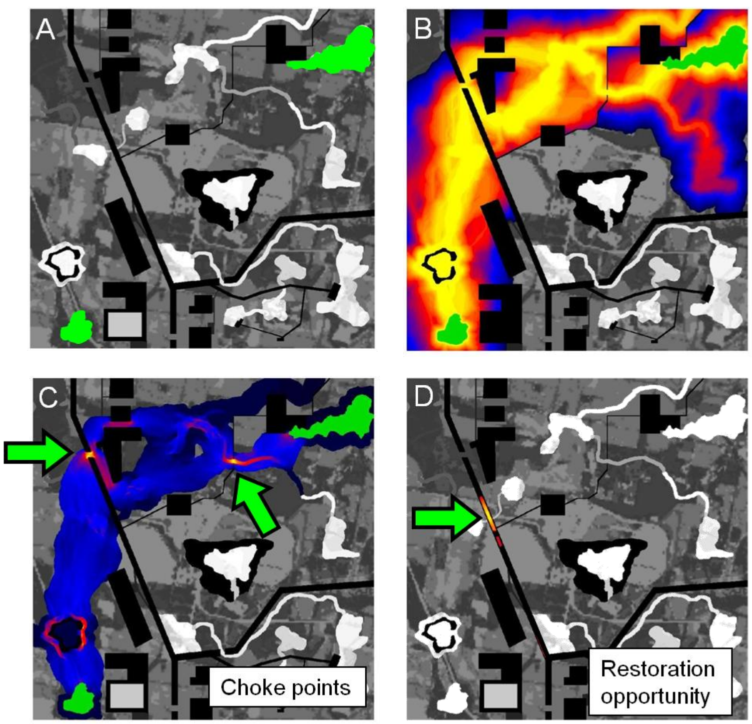

Figure 1. Example of choke points and restoration opportunities identified by least-cost and circuit theory algorithms. (A) Simple landscape, with two patches to be connected (green) separated by lands with varying resistance to dispersal (low resistance in white, higher resistance in darker shades). (B) Least-cost corridor between the patches (lowest resistance routes in yellow, highest in blue). (C) Choke points identified by *Circuitscape* within least-cost corridor. Areas where connectivity could be compromised by the loss of a small amount of habitat glow yellow. These could be prioritized over areas that contribute little to connectivity, such as the dark blue "corridor to nowhere" at the top of the panel. (D) Restoration opportunitiy detected by new circuit algorithms. If restored (e.g., with a highway crossing structure), this would re-route the corridor through a much more efficient path and reduce choke-point effects.

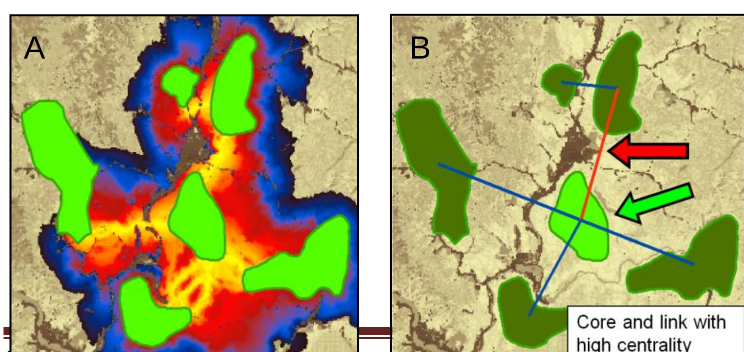

Figure 2. We will develop and share network centrality tools to inform prioritization among core areas and linkages. (A) Least-cost corridors identified by *Linkage Mapper* among core areas. (B) Network of core areas produced by *Linkage Mapper*. Arrows indicate a core area and a linkage that have high centrality. These are "gatekeepers" of connectivity because losing either would disproportionately affect

connectivity across the network (Estrada and Bodin 2008; Carroll et al. in review). A network version of *Circuitscape* would automatically analyze *Linkage Mapper* outputs to identify core areas and linkages that are most critical for maintaining connected networks.

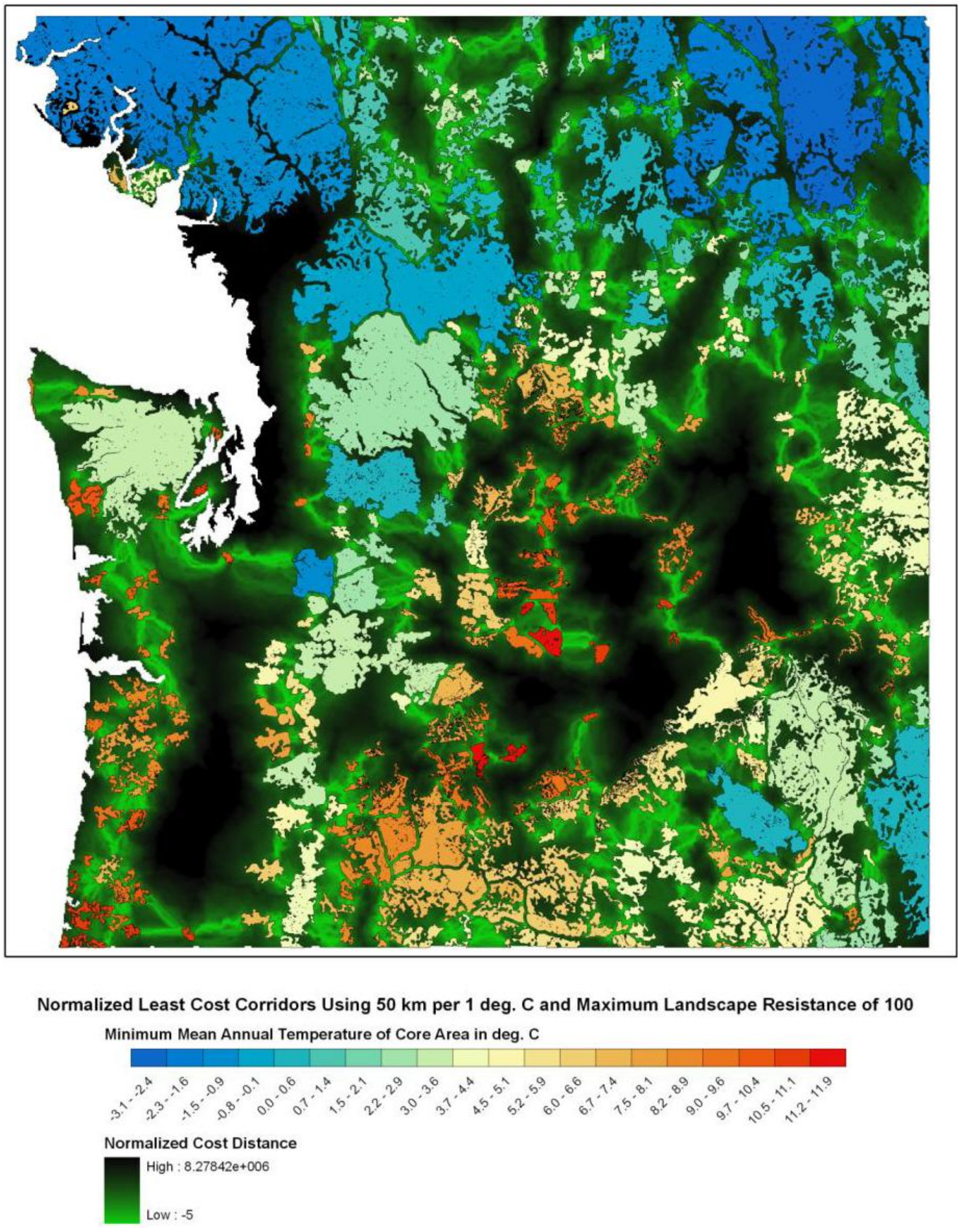

Figure 3. Prototype climate gradient linkage map developed for WHCWG statewide analysis. Areas expected to be important for species movements in response to climate change are shown in green. These climate gradient linkages connect core areas of high landscape integrity (polygons above, shaded to reflect mean annual temperatures) that differ in temperature by more than 1ºC. They thus allow for movement between warmer and cooler areas, while avoiding along the way major changes in temperature (e.g., crossing over cold peaks or dipping into warm valleys) and areas of low landscape integrity (e.g., cities or highways). With GNLCC funding, we will synthesize our new climate gradient linkage maps with WHCWG statewide map layers, and provide decision support regarding interpretation and implementation of these new climate products. NPLCC funding to create *Linkage Mapper Climate* will automate these analyses and facilitate their application across the NPLCC and elsewhere.

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Disclaimer Regarding Data Sharing:

No known restrictions. All analysis products, including GIS data and computer source code, will be made publically available.